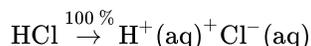


## 12.5: Strong and Weak Acids and Bases and their Salts

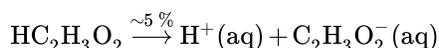
### Learning Objectives

- Define a strong and a weak acid and base.
- Recognize an acid or a base as strong or weak.
- Determine if a salt produces an acidic or a basic solution.

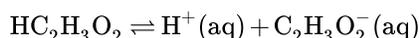
Except for their names and formulas, so far we have treated all acids as equals, especially in a chemical reaction. However, acids can be very different in a very important way. Consider  $\text{HCl}(\text{aq})$ . When  $\text{HCl}$  is dissolved in  $\text{H}_2\text{O}$ , it completely dissociates into  $\text{H}^+(\text{aq})$  and  $\text{Cl}^-(\text{aq})$  ions; all the  $\text{HCl}$  molecules become ions:



Any acid that dissociates 100% into ions is called a **strong acid**. If it does not dissociate 100%, it is a **weak acid**. Acetic acid ( $\text{HC}_2\text{H}_3\text{O}_2$ ) is an example of a weak acid:



Because this reaction does not go 100% to completion, it is more appropriate to write it as a reversible reaction:



As it turns out, there are very few strong acids, which are given in Table 12.5.1. If an acid is not listed here, it is a weak acid. It may be 1% ionized or 99% ionized, but it is still classified as a weak acid.

Table 12.5.1: Strong Acids and Bases

Acids	Bases
HCl	LiOH
HBr	NaOH
HI	KOH
$\text{HNO}_3$	RbOH
$\text{H}_2\text{SO}_4$	CsOH
$\text{HClO}_3$	$\text{Mg}(\text{OH})_2$
$\text{HClO}_4$	$\text{Ca}(\text{OH})_2$
	$\text{Sr}(\text{OH})_2$
	$\text{Ba}(\text{OH})_2$

The issue is similar with bases: a **strong base** is a base that is 100% ionized in solution. If it is less than 100% ionized in solution, it is a **weak base**. There are very few strong bases (Table 12.5.1); any base not listed is a weak base. All strong bases are  $\text{OH}^-$  compounds. So a base dependent on some other mechanism, such as  $\text{NH}_3$  (which does not contain  $\text{OH}^-$  ions as part of its formula), will be a weak base.

### ✓ Example 12.5.1

Identify each acid or base as strong or weak.

- HCl
- $\text{Mg}(\text{OH})_2$
- $\text{C}_5\text{H}_5\text{N}$

**Solution**

- a. Because HCl is listed in Table 12.5.1, it is a strong acid.
- b. Because Mg(OH)<sub>2</sub> is listed in Table 12.5.1, it is a strong base.
- c. The nitrogen in C<sub>5</sub>H<sub>5</sub>N would act as a proton acceptor and therefore can be considered a base, but because it does not contain an OH compound, it cannot be considered a strong base; it is a weak base.

### ? Exercise 12.5.1

Identify each acid or base as strong or weak.

- a. RbOH
- b. HNO<sub>2</sub>

#### Answer a

strong base

#### Answer b

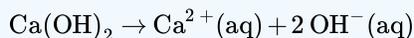
weak acid

### ✓ Example 12.5.2

Write the balanced chemical equation for the dissociation of Ca(OH)<sub>2</sub> and indicate whether it proceeds 100% to products or not.

#### Solution

This is an ionic compound of Ca<sup>2+</sup> ions and OH<sup>-</sup> ions. When an ionic compound dissolves, it separates into its constituent ions:



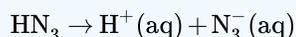
Because Ca(OH)<sub>2</sub> is listed in Table 12.5.1, this reaction proceeds 100% to products.

### ? Exercise 12.5.2

Write the balanced chemical equation for the dissociation of hydrazoic acid (HN<sub>3</sub>) and indicate whether it proceeds 100% to products or not.

#### Answer

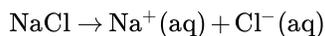
The reaction is as follows:



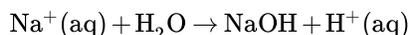
It does not proceed 100% to products because hydrazoic acid is not a strong acid.

Certain salts will also affect the acidity or basicity of aqueous solutions because some of the ions will undergo hydrolysis, just like NH<sub>3</sub> does, to make a basic solution. The general rule is that salts with ions that are part of strong acids or bases will not hydrolyze, while salts with ions that are part of weak acids or bases will hydrolyze.

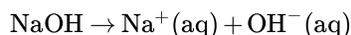
Consider NaCl. When it dissolves in an aqueous solution, it separates into Na<sup>+</sup> ions and Cl<sup>-</sup> ions:



Will the Na<sup>+</sup>(aq) ion hydrolyze? If it does, it will interact with the OH<sup>-</sup> ion to make NaOH:



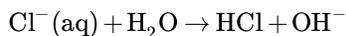
However, NaOH is a strong base, which means that it is 100% ionized in solution:



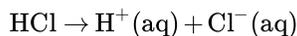
The free  $\text{OH}^-$ (aq) ion reacts with the  $\text{H}^+$ (aq) ion to remake a water molecule:



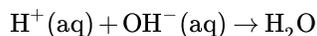
The net result? There is no change, so there is no effect on the acidity or basicity of the solution from the  $\text{Na}^+$ (aq) ion. What about the  $\text{Cl}^-$  ion? Will it hydrolyze? If it does, it will take an  $\text{H}^+$  ion from a water molecule:



However, HCl is a strong acid, which means that it is 100% ionized in solution:

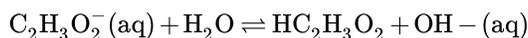


The free  $\text{H}^+$ (aq) ion reacts with the  $\text{OH}^-$ (aq) ion to remake a water molecule:



The net result? There is no change, so there is no effect on the acidity or basicity of the solution from the  $\text{Cl}^-$ (aq) ion. Because neither ion in NaCl affects the acidity or basicity of the solution, NaCl is an example of a neutral salt. A neutral salt is any ionic compound that does not affect the acidity or basicity of its aqueous solution.

Things change, however, when we consider a salt like  $\text{NaC}_2\text{H}_3\text{O}_2$ . We already know that the  $\text{Na}^+$  ion won't affect the acidity of the solution. What about the acetate ion? If it hydrolyzes, it will take an  $\text{H}^+$  from a water molecule:



Does this happen? Yes, it does. Why? *Because  $\text{HC}_2\text{H}_3\text{O}_2$  is a weak acid.* Any chance a weak acid has to form, it will (the same with a weak base). As some  $\text{C}_2\text{H}_3\text{O}_2^-$  ions hydrolyze with  $\text{H}_2\text{O}$  to make the molecular weak acid,  $\text{OH}^-$  ions are produced.  $\text{OH}^-$  ions make solutions basic. Thus  $\text{NaC}_2\text{H}_3\text{O}_2$  solutions are slightly basic, so such a salt is called a **basic salt**.

There are also salts whose aqueous solutions are slightly acidic.  $\text{NH}_4\text{Cl}$  is an example. When  $\text{NH}_4\text{Cl}$  is dissolved in  $\text{H}_2\text{O}$ , it separates into  $\text{NH}_4^+$  ions and  $\text{Cl}^-$  ions. We have already seen that the  $\text{Cl}^-$  ion does not hydrolyze. However, the  $\text{NH}_4^+$  ion will:



Recall from Section 12.2, that  $\text{H}_3\text{O}^+$  ion is the hydronium ion, the more chemically proper way to represent the  $\text{H}^+$  ion. This is the classic acid species in solution, so a solution of  $\text{NH}_4^+$ (aq) ions is slightly acidic.  $\text{NH}_4\text{Cl}$  is an example of an **acid salt**. The molecule  $\text{NH}_3$  is a weak base, and it will form when it can, just like a weak acid will form when it can.

So there are two general rules:

1. If an ion derives from a strong acid or base, it will not affect the acidity of the solution.
2. If an ion derives from a weak acid, it will make the solution basic; if an ion derives from a weak base, it will make the solution acidic.

### ✓ Example 12.5.3

Identify each salt as acidic, basic, or neutral.

- a. KCl
- b.  $\text{KNO}_2$
- c.  $\text{NH}_4\text{Br}$

#### Solution

- a. The ions from KCl derive from a strong acid (HCl) and a strong base (KOH). Therefore, neither ion will affect the acidity of the solution, so KCl is a neutral salt.
- b. Although the  $\text{K}^+$  ion derives from a strong base (KOH), the  $\text{NO}_2^-$  ion derives from a weak acid ( $\text{HNO}_2$ ). Therefore the solution will be basic, and  $\text{KNO}_2$  is a basic salt.
- c. Although the  $\text{Br}^-$  ions derive from a strong acid (HBr), the  $\text{NH}_4^+$  ion derives from a weak base ( $\text{NH}_3$ ), so the solution will be acidic, and  $\text{NH}_4\text{Br}$  is an acidic salt.

### ? Exercise 12.5.3

Identify each salt as acidic, basic, or neutral.

- A.  $(C_5H_5NH)Cl$
- B.  $Na_2SO_3$

**Answer a**

acidic

**Answer b**

basic

Some salts are composed of ions that come from both weak acids and weak bases. The overall effect on an aqueous solution depends on which ion exerts more influence on the overall acidity. We will not consider such salts here.

### Summary

- Strong acids and bases are 100% ionized in aqueous solution.
- Weak acids and bases are less than 100% ionized in aqueous solution.
- Salts of weak acids or bases can affect the acidity or basicity of their aqueous solutions.

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